

DEPARTMENT OF ECOLOGY

February 20, 2004

TO: Marcie Mangold, David T. Knight and James Bellatty
Water Quality Program, Eastern Regional Office

FROM: Jim Carroll, Watershed Studies Unit
Environmental Assessment Program

THROUGH: Karol Erickson, Unit Supervisor, Watershed Studies Unit
Environmental Assessment Program

SUBJECT: RESPONSE TO ADDITIONAL REVIEW COMMENTS ON THE DRAFT
MOSES LAKE TOTAL MAXIMUM DAILY LOAD PHOSPHORUS STUDY
TECHNICAL DOCUMENT

Introduction:

The draft Moses Lake TMDL Phosphorus Study report was distributed to the Moses Lake Advisory Board and interested parties the week of November 25, 2002. A comment period deadline of December 31, 2002 was announced for reviewers of the draft report. Ecology received written review comments from Jim Parsons (Troutlodge, Inc.), Jack Rensel (Rensel and Associates on behalf of Troutlodge), Anne Henning (City of Moses Lake), Larry Gadbois (US EPA), William Riley (Big Bend Economic Development Council), and Dean White (Lincoln County Conservation District) within the period. Jim Parsons of Troutlodge, Inc. sent additional comments on January 7, 2003 after receiving a deadline extension for that date. Additional comments were received from Jack Rensel (Rensel Associates) on January 10, 2003, presumably on behalf of Troutlodge, Inc.

Ecology also contracted with Professor Emeritus Dr. Eugene Welch (University of Washington), who has extensive experience with water quality issues on Moses Lake, to peer-review the draft report. A response summary addressing all of the above comments is available at the Moses Lake TMDL website:

<http://www.ecy.wa.gov/programs/wq/tmdl/watershed/moseslake/technical.html>.

At the October 1, 2003 Moses Lake Advisory Board meeting, members of the board requested that the Moses Lake TMDL Phosphorus Study report be reviewed again by a candidate of their choice. A list of six potential candidates to review the report was sent to Ecology by Chairman Dent. Ecology invited reviews from all six candidates. Comments were received from Dr. Peter Burgoon of Water Quality Engineering, Inc. and Dr. Clinton Shock of Oregon State University.

General Responses:

1. *Model Calibration and Model Uncertainty*: Ecology's goal was to develop a modeling tool that can be used to manage water quality in Moses Lake. While no numerical model can recreate perfectly the complex, time-varying interactions of every physical, chemical, and biological process, our goal is to have the CE-QUAL-W2 model represent the primary processes that control the fate and transport of phosphorus. The objective was to collect enough data to develop a scientifically based model application that is a **good approximation** of the system. We believe the Moses Lake CE-QUAL-W2 model was appropriately developed using the best available data. We also believe the model clearly demonstrates that it is a good approximation of the major forcing processes and features that affect water quality, such as the hydrodynamics, temperature stratification, and tributary and diffuse groundwater P loading to Moses Lake. Ideally, the model could be calibrated to more than one year of data; however, due to resource and time limitations, there is no plan to collect another year of data to confirm the model calibration. Still, Ecology believes the model is an effective tool for recommending P allocations as calibrated.

The U.S. Environmental Protection Agency (EPA) has not provided specific guidance on model uncertainty analysis or guidance on what are the “acceptable” variances for determining when a water quality model is adequately “calibrated” to a specific variable so it can be used for establishing waste load and load allocations. The goal in the model calibration is to minimize the differences between model predictions and measured values and reproduce major physical and chemical processes (e.g., hydrodynamic flow in Moses Lake, temperature stratification, and major variable concentrations). An important aspect of model calibration is to provide a model which does not have significant systematic model biases that could bias the evaluation of proposed management strategies. As part of the reporting documentation for the development of the CEQUALW2 model, we are providing commonly used error statistics for the major variables which clearly show that the model does not have any systematic biases.

2. Ecology appreciates receiving eleven sets of comments for the Moses Lake TMDL Phosphorus Study technical report. We believe the incorporation of the received comments has strengthened this TMDL project.

Beginning with Dr. Shock, reviewer comments are listed below (as italicized text) with a response following each specific comment.

Comments received by Dr. Clinton Shock on 1/15/04:

January 15, 2004

*David T. Knight
Unit Supervisor, Water Quality Program
State of Washington Department of Ecology
4601 N. Monroe St.
Spokane, WA 99205-1295*

Dear David Knight,

Thank you for asking me to review the "Moses Lake Total Maximum Daily Load (TMDL) Phosphorus Study". I will refer to the "Moses Lake Total Maximum Daily Load Phosphorus Study" in the letter that follows as the "TMDL P Study". I spent three days carefully reading the "Moses Lake Total Maximum Daily Load Phosphorus Study" and pertinent parts of Pitz 2003 "Moses Lake Total Maximum Daily Load Groundwater Study". I have examined data associated with the TMDL P Study and several other supporting references. The opinions below are my own, and do not represent the opinions of the College of Agricultural Sciences or Oregon State University.

General comments

The "TMDL P Study" was very thoughtful and competently done; however there are several key parts which deserve careful reconsideration. P movements and budgets are exceedingly complex and most of the observations and evaluations are appropriate. The efforts to model water and P in the Moses Lake watershed are impressive, and the model helps quantify changes that might occur given different management scenarios.

Importance of P in aquatic systems

It is essential and appropriate that a TMDL for Moses Lake consider the P loading to the lake. P is a key limiting element in the growth of alga and lake eutrophication. Algae and other microorganisms in the water greatly affect dissolved oxygen. Under algal bloom conditions, the algae have a negative effect on reservoir fisheries because of periodic oxygen depletion associated with algae respiration and decomposition. During the day they pick up carbon dioxide and release oxygen through photosynthesis so the dissolved oxygen in the water rises. At night their metabolism requires them to take up oxygen and release carbon dioxide. These fluctuations can be large. When an excess of algae grow and sink deeper into the water, their rate of photosynthesis can no longer be maintained, and they decompose at the cost of dissolved oxygen. Lake water samples show that total P and ortho phosphate are high and observations of Moses Lake have determined that it is eutrophic.

Response:

Ecology agrees.

Opportunities for a better understanding of the watershed

If Moses Lake has always been eutrophic, then the Department of Ecology and the citizens of Washington need to determine this fact before embarking on an ambitious restoration effort. There is a real opportunity to objectively examine the P loading and eutrophication of Moses Lake in the past. By sampling sediment cores of the lake bottom, the enrichment over the past 50 years could be compared with prior enrichment. Many very strong tools are available to help date these changes.

Response:

Carroll et al. (2000), page 33, states “A review of sediment profiles from Moses Lake revealed large and consistent P and N loads for at least 100 years, suggesting the lake probably experienced algal blooms even in its “natural” state (Patmont, 1980). Therefore, management of Moses Lake for other than a eutrophic condition has been deemed impracticable, and has not been the focus or objective of rehabilitation measures to date (Welch *et al*, 1973; Brown and Caldwell, 1980; Patmont 1980).” Restoration has always been focused on reducing the hypereutrophic conditions in the lake. The apparent fact that Moses Lake has always been a productive, eutrophic lake is part of the reason that a higher TP criterion of 50 ug/L is proposed. Ecology’s current Water Quality Standards recommend a TP criterion of 35ug/L for the Columbia Basin Ecoregion.

Opportunities for remediation

1. The strong stratification of P with depth in Moses Lake provides an opportunity to recycle P from the lake to agricultural irrigation. This can be accomplished by providing an alternative managed outflow. A deeply buried pipe could capture water richer in P, so that when the lake is diluted with irrigation water, P unloading could be greatly enhanced.

Response:

This may be addressed in the Summary Implementation Strategy (SIS) part of this TMDL.

2. The community has the opportunity to determine human caused contributions of P and take actions to reduce these contributions. Rural and domestic sewer systems in and around the town of Moses Lake would seem to deserve special attention.

Response:

Ecology agrees.

Statements and conclusions that need a stronger foundation of reason

1. Page 15, last paragraph. Hydrology of Rock Ford Creek

By carefully examining the oscillations of flows in Rocky Ford Creek (largely from the spring) prior to the development of the irrigation projects, the creek had patterns of flow somewhat similar to those after the development of irrigation. The conclusions about the influence of irrigation on the flows in Rocky Ford Creek are unsubstantiated.

Response:

Ecology's groundwater study (Pitz, 2003) did not examine and establish a cause and effect influence of irrigation recharge on the discharge rate of Rocky Ford Springs, so references to flows being influenced by irrigation will be deleted on page 15, 18, 19, 27, and 28.

Charles Pitz replied: *"My study did not examine the influence of irrigation recharge on the discharge rate of Rocky Ford Springs.....However, numerous studies have show that irrigation in the Columbia Basin project area has significantly impacted the region's subsurface and surface hydrologic regime, and has greatly altered groundwater/surface water interactions throughout the region. While the basic seasonal patterns or cycles of surface discharge, spring flow, and water table position remain intact, water management efforts and recharge from large-scale irrigation has clearly modified these patterns throughout the project area. The arid Quincy-Pasco subunit of the Central Columbia plateau (the subunit encompassing the Rocky Ford Creek/Moses Lake area) now has the highest annual recharge rate in the Columbia Basin as a result of irrigation. In turn, water table positions in the subunit have changed significantly from pre-irrigation conditions, and numerous springs and wetlands now are present that didn't exist before. Significant changes have also been imposed on the area hydrology as a result of irrigation canal leakage, installation of tile drain systems, transfers of water between project-related reservoirs, and inflows and outflows to/from wasteways. One small case study of these effects very close to the spring area is mentioned in my report under the discussion regarding the Soap Lake Protective Works. It would be difficult to imagine a scenario where irrigation project-derived recharge has not in some way altered or influenced the character of discharge at the Rocky Ford Creek spring.*

A very brief reference list of literature regarding irrigation water influence in the Columbia Basin:

- USGS Open-File Report 95-445, by Sarah J. Ryker and Joseph L. Jones
- Williamson, A.K., Munn, M.D., Ryker, S.J., Wagner, R.J., Ebbert, J.C., and Vanderpool, A.M., 1998, Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95: U.S. Geological Survey Circular 1144, on line at <URL: <http://water.usgs.gov/pubs/circ1144>>, updated March 3, 1998.
- Whiteman, Vaccaro, Gonthier, 1989, USGS Professional Paper 1413-B
- Hansen, Vaccaro, Bauer, 1994, Water Resources Investigation Report 91-4187"

2. Page 28, paragraph 1. The last line is speculation, not established fact.

Response:

Ecology agrees and will remove the sentence, as it does not add to the established facts that are being reported.

3. Page 34 and Page 101, paragraph 6. Based on the work of Bain and Pitz, the TMDL P Study concludes that the fundamental source of P in Rocky Ford Creek is from irrigated agriculture. The data on which this conclusion is based are the presumed direction of groundwater flow and the chemical characteristics of a very limited number of groundwater samples from the Brook Lake area being similar in chemical composition to the water at the Rocky Ford Springs. The data presented are insufficient to prove a cause and effect relationship for P enrichment from agriculture at Rocky Ford Spring. A reinforcing source of doubt is the Rocky Ford Spring water flow patterns prior to irrigation, which seem to be fundamentally unaltered.

The words "still dominate" at the end of the paragraph on page 34 seems odd, since the human caused effects seem to be still unproven.

Response:

Ecology will remove the last part of the sentence that states, "...suggesting that anthropogenic sources of phosphorus still dominate the source springs of the Rocky Ford Creek system."

Charles Pitz replied with the following concerning the source of P in the Rocky Ford Creek spring:

"My study never claimed to prove a cause and effect relationship between P enrichment in the spring and upgradient agricultural activities. I did attempt to lay out the facts as we know them:

- *Groundwater and hydrogeologic data indicate that the majority of the spring discharge is derived from the area northeast of the spring. As early as 1952, the USGS recognized and reported on a hydraulic connection between Crab Creek in the Adrian/Brook Lake area and the spring discharge.*
- *Land use activities hydraulically upgradient of the spring include irrigated crop farming and other activities that can release surplus phosphorus to the subsurface.*
- *The soils/sediments underlying these areas have characteristics that suggest a limited phosphorus attenuation capacity.*
- *There is abundant evidence in the scientific literature that dissolved phosphorus can be transported significant distances from source areas by advective groundwater transport, given the right aquifer conditions. Many of those conditions exist in the Rocky Ford Springs area (coarse grained calcareous aquifer sediments, low fine and organic content, high permeability rates, high groundwater velocities).*
- *The geochemistry of the spring water best matches water with a relatively short residence time in the aquifer system.*
- *Available groundwater quality data do not indicate a natural background condition for ortho-P much above ~50 ug/L, in the area of interest (as I recall, Jones and Wagner (1995) reported that ~95% of all groundwater samples collected in the basin report an ortho-P concentration less than the median ortho-P concentration measured at the spring*

during the 2001 water year). This suggests that values above this level may be derived from anthropogenic sources raising the ambient phosphorus condition in the aquifer.

- There is an extensive body of literature that has demonstrated the significant influence of irrigated agriculture on the movement and occurrence of nitrate in the Columbia Basin; many of these same factors apply to the movement and occurrence of phosphorus. Phosphorus-bearing fertilizer is applied to the irrigated land upgradient of the spring.

Again, I never claimed to prove a cause and effect relationship. I gathered and reviewed the facts and available data; to me the weight of evidence suggests that losses of phosphorus from upgradient irrigated agricultural fields is one perfectly reasonable explanation for the elevated P observed at the springs.”

4. Starting on page 62, Figure 40 through page 83, figure 58. The figures and the discussion deal with how the data was fitted to the model. Yet the results are presented as if the lake performance was predicted by the model.

Response:

Text and figure titles were changed to differentiate the model-predicted results from the observed data.

5. The modeling and P balance of Moses Lake commingles the effects of groundwater from the region close to town and nutrient contributions from surface runoff and water fowl. The discussion then deals with this fraction of P as if it was coming from groundwater.

Response:

The entire section concerning other P sources was re-written for better explanation as follows:

“Other P Sources

Other P sources not specifically allocated as seasonal P loads in this TMDL evaluation are stormwater runoff (overland flow and unknown contributions from City of Moses Lake stormwater collection system), waterfowl contributions (more than 50,000 waterfowl winter on Moses Lake each year), and net pen fish production (the state Department of Fish and Wildlife operates a facility from October to March in the South basin).

Many of these sources probably have a minimum impact during the critical season of May through September because they take place mostly in the winter. Any P loads that enter Moses Lake in the winter become part of the initial conditions for the critical season. The Moses Lake CE-QUAL-W2 model was calibrated using measured initial conditions from March 2001. These initial conditions include the sum impacts of all winter P loading including stormwater runoff, waterfowl feces, and net pen fish. Soluble P in the water column initially fuels the spring diatom bloom or is washed out as the lake is filled up in the spring. Particulate P that enters Moses Lake in the winter either breaks

down into soluble P, settles to the bottom sediments, or is washed out of Moses Lake. Any effects that P in the sediments may have from May through September are contained in the residual of the P mass balance as the internal P load term (i.e., release of P from the sediments during anoxic conditions in the summer). The Moses Lake CE-QUAL-W2 model incorporates a P-sediment release algorithm to account for the internal P load and was calibrated to the 2001 hypolimnion P data.

Even though Moses Lake receives minimal precipitation from May through September, summer thunderstorms can occur that may create non-point P loading from runoff. Lake-shore runoff can include fertilizers, pet feces, oils, and soil among other contaminants. These could lead to temporary P spikes in the Moses Lake water column and should be included in a BMP evaluation for Moses Lake.”

6. Page 88, Table 14. Rather than calculating the net P outflow, the study should have calculated an estimate from the collected data.

Response:

The Moses Lake TMDL study did not calculate a net P outflow. The outflow P load was calculated from daily outflow discharges and the simulated daily outflow P concentrations reported in the CE-QUAL-W2 model. Discharge at the outflow dam was calculated using a HEC-RAS model (version 3.0) and was calibrated by Northwest Hydraulic Consultants of Seattle. Actual discharges from 2001 were used to calibrate the model. The simulated flows had a RMSE of 71.7 cfs (CV = 7.8%; n=13) for the whole range of flows and operational ranges. The simulated outflow TP concentrations were compared to measured outflow TP concentrations and had an overall RMSE of 9 ug/L (CV = 42%; n=8) for May through September. Ecology believes this is the best estimate of the TP load discharged from Moses Lake. Again, the estimate is not a net measurement, nor is it a residual calculation from the TP mass balance.

7. P 93, paragraph 3. By using an average P content by depth, the TMDL risks being overly restrictive.

Response:

The TMDL technical report states on page 99: “When evaluating model simulations, the entire water column TP was averaged for compliance with the TP criterion. Even though the algae grow in the euphotic zone, the entire water column was averaged because Moses Lake is polymictic (i.e., capable of mixing several times during the growing season). The potential entrainment of elevated hypolimnetic concentrations of TP was considered a margin of safety and included in the available TP pool. The hypolimnion represents less than 20% of the volume of the lake. During May through September 2001, the average seasonal whole column TP was 24% more than the average seasonal euphotic zone TP in the whole lake. This could be considered an implicit 24%

margin of safety and account for the natural variation (uncertainty) associated with internal loading which has been shown to have a variability of up to 100% (Welch et al., 1989).”

Ecology recognizes that there will be data and model uncertainty associated with recommending WLAs and LAs to meet any TMDL. The Clean Water Act requires that any lack of knowledge about the system must be accounted for by establishing a margin of safety (MOS) in developing a TMDL. The implicit (conservative assumptions) or explicit (reserving a portion of the loading capacity) MOS must be identified as part of the TMDL as it undergoes public review.

As stated, there could be an implicit MOS of as much as 24%, but Ecology believes the MOS is also tempered by establishing a high TP criterion of 50 ug/L for Moses Lake. Ecology does not believe it is overly restrictive in using a whole-column average in its determination of TP for compliance with the criterion.

8. Page 99, Table 18, and Page 102, paragraph 3. The TP 35% reduction fails to deal with relative feasibilities or fairness of the P load reductions.

Response:

The proposed allocations in the technical document were presented as an initial allocation strategy, taking a first-hand cut at what might be done. The premise was that an across-the-board equal percentage reduction was a fair action, particularly for the point-source contributors. In the suggested course of action, the largest contributors (e.g., groundwater) have the largest nominal load reductions and vice versa.

The next step of the TMDL process includes developing a Summary Implementation Strategy (SIS) that takes input from the public through the Advisory Board to address the most effective and economical means of reducing P in Moses Lake. The bottom-line in the technical report is that the P lake-response model shows that a maximum external P load of 6,340 kg TP is allowable from May through September in order to meet the 50 ug/L TP criterion (in 9 out of 10 years on the average). How the reductions are divided between sources can be addressed in the development of the SIS. As is often the case for non-point sources, it may be that further assessment is needed to address a particular non-point source. That appears to be the case for Rocky Ford Creek, as the source of elevated P in the springs is unknown. On the other hand, other non-point sources, such as wastewater contributions to groundwater, could begin to be addressed immediately.

My sincere thanks for the opportunity to review the TMDL P Study. I have attached a list of smaller issues and technical corrections and questions.

*Dr. Clinton C. Shock
Superintendent and Prof.*

Technical corrections and questions (35 items)

1. Abstract, line 1. Edit to read "... especially irrigation, lake P dilution with irrigation water flow through, and urban development."

Noted and changed in the text.

2. Abstract, paragraph 3, line 2. Substitute "estimate" for "evaluate".

Noted and changed in the text.

3. Page 1, paragraph 6. Edit to read ".. now 15 years old."

Noted and changed in the text.

4. Page 2, paragraph 4, last line. The years of occurrence and references are lacking.

Added citation – “Carroll et al, 2000” to text. This document reviewed the historical studies from 1964 through 1989.

5. Page 2, paragraph 5, line 2. References are missing.

Removed line 2. Added line referencing observed blue-green algae bloom in 1998. This was supposed to be a short history and not a justification as to why Moses Lake was on the 303(d) list (see general comment #1 above).

6. Page 7, paragraph 1. Please state the frequency of measurements.

Stated in text that samples were taken approximately monthly from March to September

7. Page 7, paragraph 3. The word "biovolume" does not have a clear meaning. Do you mean to say "concentration"? In what units?

The unit “biovolume” is a calculated unit by Jim Sweet of Aquatic Analyst. It is in cubic micrometers per square centimeter. He multiplies the density of a single species ($\#/cm^2$) times the mean unit biovolume for that species. This is also in Standard Methods (1998) as method SM10200I.

8. *Page 7, paragraph 4. Starting here, all designations of locations should be consistently named in all figures, tables, and the text. As written, the text needs substantial careful cross referencing by the cautious reader to figure out what spots are under consideration. For example, see the legend of Figure 6 on page 17, the locations at the top of page 18, etc. I figured them all out at considerable effort.*

The confusion seems to be caused by stations that were not Ecology project stations (e.g., USGS stations). The text was changed to associate Ecology station names (which are correctly mapped) with these stations so they can be located on the location maps provided.

9. *Page 9, paragraph 5. Please specify the accuracy and inaccuracy ranges of the tests.*

The following was added to the text: "The pooled average difference between Winkler and meter readings was 0.12 mg/L with a pooled RMSE of 0.44 mg/L."

10. *Page 10, paragraph 1. The dense algal bloom reported here is in contradiction to the lake P level. This is disconcerting.*

Agree. There is no corroborating evidence of "an extremely dense algal bloom" in either the lab data or the field notes for that date. The sentence will be deleted.

11. *Page 10, Table 2. The "blank" levels for total P and orthophosphate are vastly too high. The public could understand the table if these were "detection limits", not "blanks".*

Text was changed to explain that the field blanks had no detections above the reporting limits for the parameters.

12. *Page 11, line 7. Should read "(for TP)"*

Noted and changed.

13. *Page 11, paragraph 3. Omit the jargon word "analyte" which makes it harder for the public to read the report.*

Noted and removed "analyte" from text.

14. *Page 11, paragraph 6. Please clarify the bias.*

The bias for the check standards had a CV of 12.7%.

15. Page 12, Figure 2. For public understanding, the graph should have the same scale in x and y and have decimal units on the axis. Some of the other graphs share these problems, so the comment will not be repeated.

This is an artifact of the word processing Ecology uses. Most of the graphs had the same scale in the Excel files they were created in, but when imported into the Word document, Word automatically re-scaled the graph to fit the format of the document. Ecology apologizes for any difficulty in the interpretation of the data on the graphs because of the re-scaling, but the data and relationships are still accurate. We will try to fix them if we can.

16. Page 13, paragraph 2. Omit "matrix spikes" here and elsewhere in the text and add "samples spiked with higher P concentrations" so the text is readable by the public.

The text was changed throughout the document to remove "matrix spikes" and replace with the suggested change.

17. Page 15, paragraph 3. The words "primary productivity" will not be generally understood by the public.

Changed "primary productivity" to "algal/plant growth"

18. Page 15, paragraph 5. Based on what years?

A citation is included (Carroll et al, 2000). The TP load data was calculated using average monthly flow from 1960 to 1999 and average monthly TP concentration reported from 1964 to 1989. This was done as part of the historical review of data.

19. Page 18, paragraph 2, line 7. Edit to read "...a 33.7 cfs or 69.2 % increase)."

Error concurred. Edited text to read "a 33 cfs or 68% increase".

20. Page 19, figure 7. Clearly state in the legend that the estimated flow is a calculation, not a measurement.

Changed the text of Figure 7 title to include "Estimated flows are made using straight-line interpolation between measured instantaneous flows"

21. Page 19, paragraph 1. Relate the higher flows to the rainfall pattern.

It was not an objective to relate higher flows in Rocky Ford Creek to rainfall patterns, particularly because Rocky Ford Creek is spring fed.

22. Page 28. The mixed units in figure 11 do not make sense.

It has been Ecology's practice to calculate a conductivity load with the units that conductivity is measured in (umhos/cm) times the flow (cfs). There is a standard method to convert conductivity to a dissolved solids concentration from which a load of dissolved solids could be calculated, but it would be a redundant effort to using the conductivity load as expressed in the report.

23. *Page 30, last paragraph. Whether the detention pond is or is not silted in is an objective fact. If it is silted in change the text to "... and is silted in" and change the text to "... it acts as an ineffective barrier ..."*

The text was changed as suggested.

24. *Page 31, paragraph 3. Replace the word "normal" with the word "average".*

The text was changed as suggested.

25. *Page 31, paragraph 4. Clarify whether the P contribution is seasonal or annual.*

Estimates were based on the average of the samplings for 1997, which were done in August and November (seasonal). Changed text to include this information.

26. *Page 33, paragraph 1. "Annual estimated total P loads ..."*

Noted and changed.

27. *Page 37, paragraph 1. Why are there water quality standards for Crab Creek when it did not even flow during the summer prior to irrigation?*

It is a water of the State of Washington.

28. *Page 37, paragraph 3. The claims in the first two sentences are not supported by scientific evidence.*

Presumed the page number was supposed to be "Page 39" rather than "Page 37". First two sentences were deleted from the text of Page 39, paragraph 3.

29. *Page 47, paragraph 2. "... were generally low, ..."*

Noted and changed.

30. *Page 47, last paragraph. Emphasize how this water represents a substantial dilution.*

Added sentence to text: "This still resulted in a dilution because the higher TP concentration lake-water was displaced and washed out of the outlet."

31. On page 51 the discussion of the model needs to mention how evaporation was considered.

Added sentence to text: "CE-QUAL-W2 has an internal evaporation model that was used to estimate evaporative water loss."

32. Page 77, last paragraph. The P outflow numbers have a very large error term.

The outflow TP concentrations appear to be slightly biased high. The average difference between the observed and predicted concentrations was 6 ug/L (n=8) for May through September data with a RMSE of 9 ug/L. The rather large CV of 42% was because the observed average TP concentration was so low (22 ug/L TP) for that time period.

33. Page 101, paragraph 6, last sentence. "... switch from surface rill or furrow irrigation to sprinkler irrigation)."

Noted and changed in text.

34. Page 103, paragraph 3. The last sentence is speculation and should be omitted.

The following sentence was removed from the text as it does not pertain to the Moses Lake TMDL: "Reducing phosphorus probably will help address pH listings in the upper Crab Creek watershed."

35. Page 103, paragraph 3. The claims in the first two sentences are not supported by scientific evidence.

The following portion of the text was removed: "..., essentially flushing the Crab Creek store of nutrients into Moses Lake."

Comments received by Dr. Peter Burgoon on 1/15/04:

To:

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From:

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Clearly a lot of work has been done to model the lake and provide a good basis for establishing a TMDL. However, the TMDL study and supporting documentation (Carroll et al 2000) fall short in establishing and presenting any argument that the BMPs implemented over the last 20 years are ineffective for protecting current use and recreation in the lake. Although phosphorus goals of <50 ug/L were not met with the BMPs, the beneficial uses have improved. There are no reports referenced in the TMDL Study or Carroll et al (2000) since 1989 that support the premise that a TMDL is required to eliminate existing blue green algae problems or other degradation of beneficial uses in the lake. Blue green algae that dominated in 1989 (Welch et al), Microcystis and Aphanizomenon, both pose serious public health hazards due to release of cyanotoxins. These algae cause regular closures of lakes in Washington but Moses Lake has not had any public health advisories within the last 15 years due to blue green algae. There is no documentation that beneficial uses are impaired in the lake since the implementation of dilution, BMPs, and management efforts of the Moses Lake Irrigation and Rehabilitation District (MLIRD). If beaches have been closed, nuisance odors produced, or fish kills have been documented in the last 15 years shouldn't they be referenced.

Response:

The technical study's sole objective was to assess the TP assimilative capacity of Moses Lake with respect to the in-lake proposed TP criterion of 50 ug/L. Data were collected and analyzed in the assessment, and a TP allocation plan was recommended to achieve the in-lake TP criterion. TMDL studies focus on the whether or not the water body meets the water quality criteria, assuming they are the appropriate targets to protect the beneficial uses.

Ecology agrees that the beneficial uses of Moses Lake have improved since the 1960s and 70s as a result of water quality restoration measures to the lake and watershed, most notably the large additions of Columbia River water (dilution water) to the lake beginning in 1977. The restoration measures (mainly dilution) have worked so well that Moses Lake, at times, meets the P goal of <50 ug/L.

Another effective BMP was the 1984 cessation of discharging Moses Lake WWTP effluent into Pelican Horn. Welch et al, (1989) clearly showed the resulting dramatic reduction of TP from Pelican Horn, a decline that seems to be continuing today probably as a result of another BMP that increases circulation in Pelican Horn (MLIRD seasonally pumps water from Parker Horn to Pelican Horn) combined with the burial of high-P sediments.

However, Ecology documents also clearly show a year-to-year climatic effect on the water quality of Moses Lake. During years with wet winters in the upper Crab Creek drainage, high winter run-off can fill Moses Lake and Potholes Reservoir to the point that very little Columbia River water (i.e., dilution water) is required the following irrigation season. This high winter runoff occurs about 4 out of 10 years on the average, most recently in the late 1990s.

In Carroll et al (2000) on page 37, two references are given (Bain, 1998 and Hallock, 1999) for data collected during the “wet years” of 1997 and 1998 that show that the beneficial uses in Moses Lake were impaired. Bain specifically compared his 1997 data with the established quantifiable water quality goals for TP, chlorophyll a, and water clarity (secchi disk) and found the targets were not met. Hallock’s 1998 data was published in 2000 (Water Quality Assessments of Selected Lakes Within Washington State, 1998; Smith et al, 2000; Department of Ecology; Publication No. 00-03-039; available on the web at: <http://www.ecy.wa.gov/biblio/0003039.html>) and shows that the TP criterion was not met and includes descriptions of “thick” Aphanizomenon blue-green algae blooms occurring throughout the summer months.

It is important to distinguish what “BMPs” are being discussed here. Clearly, the use of Columbia River water to dilute Moses Lake is the most effective BMP to date, and the data clearly shows that not only have the beneficial uses improved (with the exception of a growing aquatic weeds nuisance), but Moses Lake also meets the goal of having less than 50 ug/L of in-lake TP when adequate dilution water is available. Moses Lake could have been described as nearly mesotrophic in 2001. Again, adequate dilution water is not available every year and the TMDL is proposing a reduction in TP loading to protect beneficial uses during years when adequate dilution water is not available.

There is reliable anecdotal evidence from MLIRD that the lake ecology has changed due to implementation of BMPs. Specifically, the necessity for removal of macrophytes with harvesting equipment has increased dramatically over the years. This implies that problems of low visibility due to algae have been resolved resulting in rampant growth of submerged aquatic plants. This has resulted in impairment of beneficial use for boating and may impact fisheries. The result is an intensive annual effort to remove the nuisance vegetation. Generally these plants are significant problems in both mesotrophic and eutrophic lakes. Given the significant quantities of phosphorus in the sediment is it reasonable to assume that the TMDL will not help in control of submerged aquatic plants?

Response:

Anecdotally, there is agreement that the need for harvesting has increased dramatically in recent years (unfortunately, MLIRD does not have written records for their macrophyte harvesting program). Your assessment of visibility is correct. Yes, it is reasonable to assume that with no high, winter run-off events the last 4 or 5 years, large amounts of Columbia River water (supplemental feed water) have been diverted through Moses Lake to Potholes Reservoir for irrigation (enough water was run through Moses Lake from March to September 2001 to fill the entire lake twice-over). Water quality attributes of the Columbia River water include very good water clarity. When Moses Lake is filled with Columbia River water, light penetrates the clearer lake water and macrophytes emerge in the shallow parts of the lake. This is particularly the case in shallow parts of Parker Horn where the Columbia River water is introduced to Moses Lake and Pelican Horn where Columbia River water is pumped from Parker Horn. There is insignificant macrophyte growth in the rest of the lake.

Because Moses Lake is eutrophic, sediment P has been and probably always will be sufficient for macrophyte growth. Macrophyte growth in Moses Lake will most likely always be limited only by light penetration so it really is a water clarity issue. It is a case of “too much of a good thing” where the “dilution water” program is creating very good water clarity which allows the macrophyte growth. The TMDL does not propose control of the dilution water and thus the macrophyte problem will continue with the additions of Columbia River water. If they were available, records would show there were less macrophytes in 1997 and 1998 in Parker Horn and Pelican Horn when the water clarity was very poor. There are very few macrophytes in the upper end of the Rocky Ford Arm (despite shallow P-rich sediments) because there is poor water clarity there every year. The proposed TMDL and the TP criterion of 50 ug/L support eutrophic conditions in Moses Lake, meaning there will be enough P in the water, in a year without dilution water, to support enough algal productivity (i.e., less water clarity) to minimize macrophyte growth.

On the other hand the growth and removal of the submerged aquatic vegetation may have beneficial impacts on phosphorus reduction in the lake. There are two important points to consider.

First, in proper conditions, submerged aquatic vegetation cause significant rates of precipitation of phosphorus from the water column. The calcium precipitate formed in alkaline water is relatively insoluble and occurs at rates much greater than can be achieved through TP removal via uptake in wetland plants. Wetland filters, using submerged aquatic vegetation, are being implemented in Florida to protect the Everglades, a national park, from TP in agricultural runoff. Pilot testing of filters in the Lake Chelan area have regularly achieved removal of >80% of the soluble reactive phosphorus and >50% of the TP during the growing season.

Secondly, removal of P by harvest of wetland plants has always been considered impractical due to the cost of harvesting. In this case harvesting in Moses Lake is paid for by lake users and

preliminary estimates show that significant enough amounts are removed to have significant TP load reduction. Based on TP and water content in the submerged aquatic vegetation in Manson Lakes (Burgoon-unpublished data) the MLIRD may have removed from 20 – 30 kg of phosphorus in 2003. Although this is only about 2-3% of the recommended reduction of 1000 kg/yr, the MLIRD harvest was low for 2003. It is also significant since it is about equal to the 35% reduction estimated for the Columbia Basin Hatchery (Table 18 of TMDL study).

Can the model be improved to account for the impacts of growth and removal of submerged aquatic vegetation? Shouldn't significant natural changes in ecology and lake management be integrated into the model?

Response:

A subroutine has been developed for CE-QUAL-W2 that models the growth of macrophytes (but not the harvesting) which may be available in the next version of the model. Ecology believes the extent of macrophyte coverage in the whole lake is minimal and for now is a minor player compared to the other forcing processes that affect water quality in Moses Lake, but macrophytes could be added in the future to the Moses Lake model.

On p 89, the TMDL Assessment summarizes the problems and solution. A bulleted paragraph discusses "A link between TP and an endpoint indicator, Chlorophyll a concentration" that was established historically and was the basis for the 50 ug/L TP. On page 90 discussions continues with, "The goal of this TMDL is to manage and mitigate the extensive hypereutrophic blooms of blue green algae that have occurred since the inception of the CBIP." As mentioned above there is no documentation that blue green algae blooms have been a problem in the last 15 years.

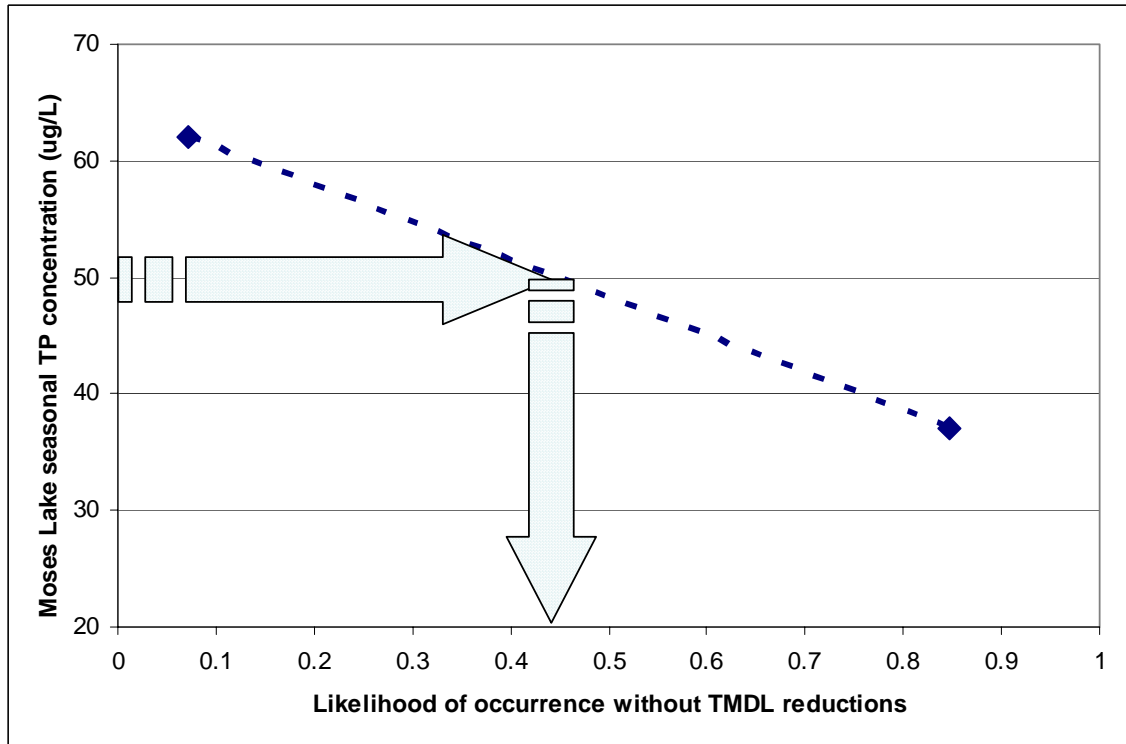
Response:

See above response to the first comment concerning Ecology 1998 data (Smith et al, 2000).

If the purpose of the TMDL is to protect against blue green algae blooms, then a probability of protection would be helpful to assure that efforts will protect the beneficial uses of the lake. For instance, could a statement be made that without the TMDL beneficial use may be impaired X% of the time but with the TMDL beneficial use will be achieved y% of the time?

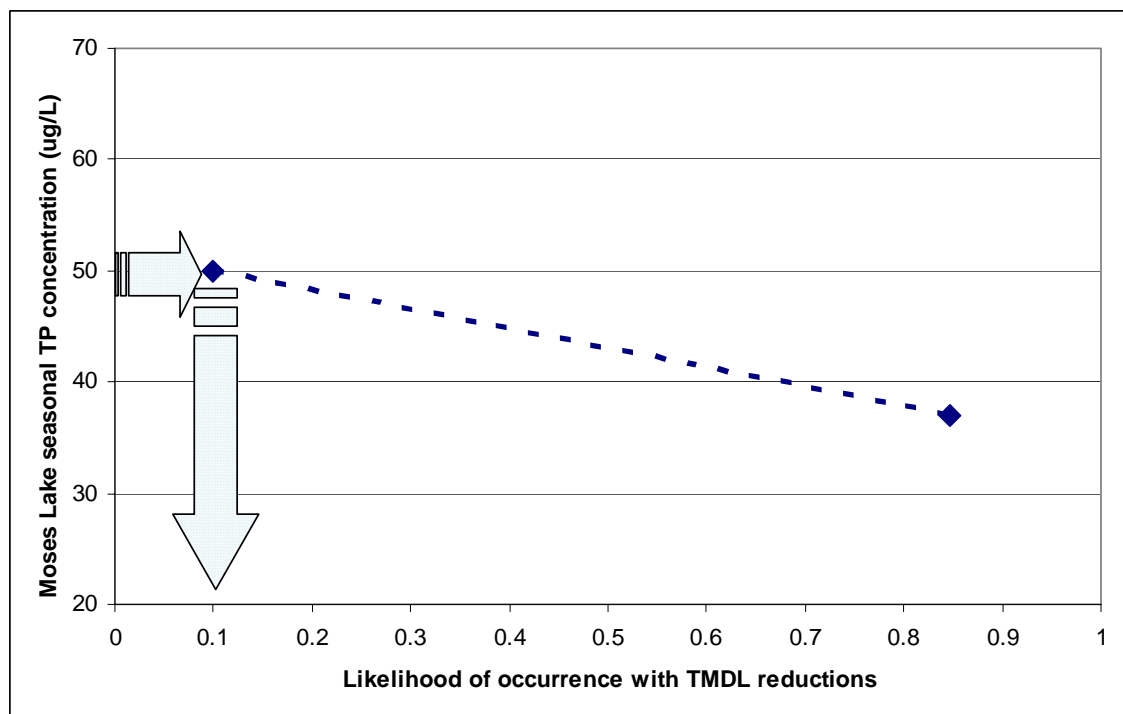
Response:

Yes, without a TMDL Moses Lake may exceed 50 ug/L of TP roughly 40% of the time on the average (or the beneficial uses of Moses Lake may be impaired roughly 40% of the time on the average). This is best illustrated by the figure below:



The Moses Lake TMDL technical analysis established that the seasonal in-lake TP concentration for 2001 and a defined critical design year (i.e., a year without adequate dilution water) were 37 ug/L and 62 ug/L, respectively. These two years are representative of two extremes (approximate lower and upper 10th percentiles) of dilution water flow to Moses Lake through Rocky Coulee Wasteway based on the probability distribution of dilution water flows from 1977 to 2001. This data is plotted on the above figure. Using linear interpolation between these two points, the current likelihood of a particular year exceeding a seasonal 50 ug/L TP concentration would be slightly greater than every 4 out of 10 years on the average.

With the TMDL the likelihood of Moses Lake exceeding the 50 ug/L of TP criterion would be approximately 10% of the time on the average. This would be illustrated by pivoting the linear line in the above figure as approximated in the figure below:



Is it valid to claim or imply that keeping the TP below 50 ug/l will control excessive blue green algae? There are several studies from lakes in western Washington that show that problems with blue green algae and release of cyanotoxins are simply unpredictable. Even in mesotrophic lakes, closure is often required due to excessive growth of blue green algae and public health concerns.

Response:

Ecology agrees that blue-green algae blooms can be unpredictable, however the goal of the TMDL is not to eliminate, but to reduce the likelihood of occurrence of excessive blue-green algae blooms in Moses Lake. The 50 ug/L TP criterion has been adopted from historical Moses Lake studies as a level that has been shown to be achievable and protective of the beneficial uses of the lake by reducing likelihood of excessive blue-green algae blooms.

As I understand the model development, it was calibrated using the data collected in 2000-2001 and then used to predict appropriate load allocations. On p 77, Table 12 shows that some stations are better modeled than others. The Study notes that a RMSE of 9 ug/L TP (18% of 50 ug/L target) is “very good” for some of the lake stations and appears to be about the best that the model can do. The RMSE for all stations is 14 ug/L (28% of 50 ug/L). Most stations have greatest RMSE in July, August, and September when blue green algae blooms maybe expected to be worst. ML3 was the worst with a maximum RMSE of 42 ug/L in May and a station average of 21 ug/L. Please clarify how the TMDL accounts for this relatively large error in the model when it states that a 35% across the board reduction in TP is required. How effective can the model be if the error is often as large as the required reduction in concentrations?

Please see general response #1 in the beginning of this response summary. It is important to step back and look at the overall model response instead of focusing on a few discrete data and model comparisons. It is important to observe if the model is behaving in a manner that shows there are no systematic errors. For example, it is clear that the model is accurately predicting increasing TP in the deeper bottom waters of Moses Lake through the summer even though the prediction error is greater because the values are much greater.

It is also important to realize that the RMSE for a single station on a certain date is an error analysis comparing all model-predicted and observed data values for the whole water column at that station. If we were to average all the values for the water column (like what has historically been done for simpler steady-state modeling), the error would be much less. Because the Moses Lake CE-QUAL-W2 model is predicting TP at one-meter depth increments at a station, there may be considerable error in the model's capability to predict a single observed TP value at a given depth interval if there is a strong TP gradient change (as in the bottom waters). The power of the Moses Lake CE-QUAL-W2 model is how often the model did accurately predict the observed values at a given observed depth. When the model did not, it often did within only a few meters above or below the observed value's depth, as can be seen in the calibration Figures 53-58.

Because most of the errors for a single station were for bottom waters where there were strong gradient changes, an error analysis of only the epilimnion (upper water above 6 meters) was conducted to quantify the error in the zone where algae grow. The following is a reproduction of Table 12, looking at the epilimnion-only error:

| TP mg/L | RMSE error statistics by site and month | | | | | | |
|-----------|---|-------|-------|-------|-------|-------|----------------|
| | ML5 | ML4 | ML3 | ML1 | ML2 | ML6 | Total |
| March | 0.003 | 0.001 | 0.007 | 0.005 | 0.005 | 0.011 | 0.006 |
| April | 0.005 | 0.006 | 0.006 | 0.008 | 0.008 | 0.006 | 0.006 |
| May | 0.007 | 0.005 | 0.008 | 0.005 | 0.012 | 0.005 | 0.007 |
| June | 0.004 | 0.010 | 0.009 | 0.007 | 0.007 | 0.008 | 0.008 |
| July | 0.014 | 0.004 | 0.010 | 0.016 | 0.014 | 0.006 | 0.012 |
| August | 0.005 | 0.013 | 0.015 | 0.016 | 0.015 | 0.007 | 0.014 |
| September | 0.012 | 0.014 | 0.009 | 0.015 | 0.013 | 0.005 | 0.012 |
| | | | | | | | Overall |
| Mar-Sept | 0.007 | 0.009 | 0.009 | 0.012 | 0.011 | 0.007 | 0.010 |

As can be seen, the error associated with the model-predicted values is much lower, with an overall RMSE of 10 ug/L TP. The model does a very good job of predicting TP even in the months of July, August, and September (when blue-green algae blooms are expected). For station ML3, there was a RMSE of 8 ug/L TP in May and a station average of 9 ug/L TP in the epilimnion. Ecology believes the Moses Lake CE-QUAL-W2 model is adequately calibrated and is an effective tool for recommending seasonal P allocations to limit exceedences of the 50 ug/L TP criterion.

The TMDL needs to better establish that the model is a reliable management tool for the lake. The modeling effort shows that there is significant error in prediction of TP, the primary TMDL parameter. The real proof of a model is in its ability to model other data sets. Some effort to show that the model can simulate conditions measured in at other times may help establish the credibility of the model and provide additional sensitivity analysis to improve the model. Can the model predict the trends that have been documented to date?

As discussed in the response to the previous comment, Ecology disagrees that there is significant error in the capabilities of the Moses Lake CE-QUAL-W2 model to predict TP. Again, as stated above, Ecology believes the Moses Lake CE-QUAL-W2 model is a reliable tool for predicting the fate and transport of phosphorus. Please also see general response #2 in the beginning of this response summary.

Ecology would like to make it clear that it agrees that conditions in Moses Lake have improved since restoration measures were implemented in the 1970s. This means that the parameters or calibration of the model would have to be changed from the current calibration for the Moses Lake CE-QUAL-W2 model to predict historical conditions and trends. Not that this wouldn't be an instructive endeavor to show the models credibility, but it probably would not improve the calibration of current conditions. Another year of data collection would be necessary for a model confirmation of current conditions.

The model should be available as a tool for future managers to make decisions for implementation of an SIS. Can the model be used to help stakeholders decide how to make the most effective decisions? For instance, could simulations be run showing the effects of a 50% reduction in phosphorus from groundwater if sewer discharges are controlled? This is only one example; obviously numerous other scenarios are possible. The main point is that the SIS process needs tools and information to help make effective decisions. The model should be made available for refinement and possible use as a management tool.

The Moses Lake CE-QUAL-W2 model will be made available to any parties interested. It would be a useful tool for making further lake management decisions such as you have described. However, it should be noted that the model can be cumbersome to set up, particularly if there are hydrologic changes, which would require the water balance to be redone. If decisions are needed during the SIS implementation, Ecology's Eastern Regional Office may request that additional modeling scenarios be developed for that process.

References:

Carroll et al. 2000. Moses Lake Proposed Phosphorus Criterion and Preliminary Load Allocations Based on Historical Review. DOE Publication No. 00-03-036

Burgoon. 2004. Unpublished data. Three filters have been operated for two growing seasons north of Lake Chelan. The project is being used to test use of submerged aquatic vegetation filters for removing phosphorus from agricultural drain water.

Bain 1998. Water Quality Monitoring Report. Prepared for Moses Lake Irrigation and Rehabilitation District.